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**Climate protection from an engineering perspective – innovative research projects at the University of Miskolc\*\***

**ABSTRACT:** In the 21st century, technical and engineering higher education, along with industrial companies, play a crucial role in addressing climate change challenges. Universities and research institutes educate specialists, engineers responsible for developing sustainable technologies and innovations essential for climate protection. Decision makers and industrial companies not only adopt these technologies but also strive to make their operations more sustainable, directly contributing to the reduction of global carbon emissions.

Joint research and development (R&D) efforts bring together higher education, industry, and research institutions to develop technologies and solutions aimed at mitigating the impacts of climate change. These collaborations are vital across multiple areas (energy, renewable energy utilisation, agriculture – precision farming, raw materials, circular economy, etc.).

Furthermore, education is undergoing significant transformation to meet the demands of climate change and the evolving needs of industry. New courses, disciplines, and training programs are being developed to equip students with the knowledge and skills required to address climate-related challenges. Universities and technical institutes are introducing specialized programs focused on renewable energy, sustainable engineering, environmental management, and green technology.

In this article I would like to present the main achievements of the engineering disciplines of the University of Miskolc - especially the Faculty of Earth and Environmental Sciences and Engineering - through projects directly or indirectly related to climate change and climate protection.

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**KEYWORDS:** climate protection, engineering, university R&D, sustainability, earth sciences.

## **1. Introduction**

Climate change is one of the greatest global challenges of our time, which requires urgent and comprehensive solutions. Higher education and research and development play a key role in finding answers to this complex problem. Universities and research institutes contribute to climate change mitigation by developing innovative technologies and sustainable solutions, while training professionals – engineers who will be able to respond to the changing needs of industry and society in the future. Through education and R&D cooperation, we develop new methods and technologies that are essential for creating a sustainable future.

Of course, the technical faculties of the University of Miskolc: the Faculty of Earth and Environmental Sciences, the Faculty of Materials and Chemical Engineering, the Faculty of Mechanical Engineering and Informatics, are trying to respond through both undergraduate and postgraduate training, training developments, and domestic and international research.

## **2. Education and climate change**

The educational portfolio of the three technical faculties includes, among others, undergraduate and postgraduate training, short courses, and further training tailored to corporate needs, which indicate that the faculties are constantly striving to develop training in line with the challenges of the times. The model curriculum reviews are carried out with the involvement of alumni from renowned companies in the given sector, thus ensuring quality curriculum changes. As a result of these professional review processes, the topic of sustainability and climate protection has been incorporated into subject topics at a certain professional and more general level.

In the case of undergraduate and master's degrees in technical geosciences, environmental engineering, geography, materials and chemical engineering, mechanical engineering, energy, and information technology, students can choose from specializations specifically related to climate change mitigation and sectors related to climate change (energy, renewable

energy production and utilization, water and raw materials research, waste management - recycling, CO<sub>2</sub> storage). Since 2022, thanks to an EIT program, the TIMREX specialization in the master's degree in geosciences engineering offers Double degree training for students wishing to deal with raw material research and research of critical elements. Thanks to the TIMREX program, in addition to the University of Miskolc, students can also study at the universities of Zagreb, Lulea, Wroclaw, and, from 2025, the Montanuniversität Leoben. Also starting in 2025, a double degree program will be created in the Master's Department of Petroleum Engineering, where students who choose the program can acquire knowledge of subsurface field development, subsurface CO<sub>2</sub> and hydrogen storage.

Our graduate programs can be studied in both the basic and master's departments in a dual format, during which a company phase also appears. In addition to the mandatory professional internship for students (6 weeks in the basic department, and 4 consecutive weeks in the master's department), they also spend 22 weeks per year at the company offering dual position. This way, in addition to the salary, they can immediately see the applicability and utilization of their studies in practice. For students who do not wish to commit to a professional partner for a longer period of time (more than 4 semesters) and would like to focus on their university studies, but would like to write a thesis in addition to project-based education with industrial partners in their final year (in exchange for payment), cooperative training has been developed and introduced, which can also be called the "little brother" of dual training, only in the last 2 semesters it means a "load" of 100-110 working days for students, ideally at the future employer.

In the case of specialized further training courses, the expansion of the 2- and 4-semester postgraduate training portfolio can also be observed in response to climate change and related areas. Without claiming to be exhaustive, the following postgraduate training courses have appeared in the portfolio of the 3 technical faculties over the past decade: Nuclear Power Plant Operation Engineer, Solar Power Plant and Solar Collector Installation Engineer, Geothermal Engineering, Hydrogen Supply Engineering, Waste Management and Utilization Engineering, Climate Adaptation Engineering, Precision Soil Mapping Engineering, Urban Operation Engineering, Sustainable Energy Engineering, which courses offer a focused opportunity to acquire immediately usable practice-oriented knowledge.

A total of 14 undergraduate, 16 master's and 16 postgraduate courses can be found in the range of programs offered by the University of Miskolc in the 2024/2025 academic year.

In addition to higher education - adult education, the technical faculties also pay special attention to ensuring the appropriate supply of students. In addition to additional energy expenditure, they offer popular science and engineering lectures for secondary and primary schools, during which they present, among other things, the issues of climate change - climate adaptation, renewable energy sources, sustainability, and how they can contribute to a livable future/environment as engineers after completing their bachelor's and master's degrees. Such programs include the lecture series entitled "Sustainability as an Engineer" and "Climate Change? Should We Fear or Adapt?", within which teaching colleagues have been touring the regions of Hungary during the school years since 2023 as a roadshow, and they also go to secondary and primary schools upon invitation.

Finally, short courses and needle-like training courses should be mentioned, which open up new opportunities for increasing the competence of company employees in expanding the knowledge base related to a specific sub-area (e.g. sustainability, climate change, climate adaptation). Such sub-knowledge training courses include the course created in the field of teacher training in 2024, entitled "Environmental sustainability in practice from school to professional". With this training, the Faculty of Earth and Environmental Sciences and Engineering, with the active participation of the lecturers of the other two technical faculties, aims to provide primary and secondary school (but not exclusively) science teachers with up-to-date, new knowledge related to the topics of sustainability and climate change, as well as to present and transfer low-cost experiments that can be implemented in schools or even in the students' homes.

### **3. International Research Projects**

The greatest added value of higher education institutions in the field of technology and natural sciences is in research and development, in addition to the training of well-educated, practice-oriented students. At the University of Miskolc, the 3 technical faculties have an extensive domestic and international network of corporate, research and higher education institutions, which in many cases look back on a history of several decades, even nearly a century (hydrocarbon exploration, production and storage). In

the next chapter - without claiming to be complete - I would like to briefly present the main domestic and international research and developments with a focus on climate change and sustainability, implemented under the leadership or participation of the Faculty of Earth and Environmental Sciences and Engineering, seeking and providing answers to these challenges.

As mentioned in the introduction, the process of climate change, its effects and the mitigation of the effects of climate change are complex topics, to which the technical faculties are connected in many areas. New, innovative research and development play a major role in the areas of raw material research and production, raw material production, CO<sub>2</sub> storage, utilization of conventional and renewable energy sources, environmental protection, identification of pollution sources and disposal of natural resources, waste management, collection of environmental data and its interpretation from a geoscientific and environmental science perspective, with the help of which we can contribute to mitigating the effects of climate change, achieving a greater degree of climate adaptation and creating adoptable good practices.

### ***3.1. 7th Framework Programme projects***

The 7th Framework Programme (FP7) of the European Union, which ran from 2007 to 2013, was one of the largest research and innovation funding schemes on the continent, with a budget of nearly €55 billion. The programme provided significant support to universities, research institutes and industrial actors and played a fundamental role in strengthening European research collaborations. The University of Miskolc also participated in several FP7 projects, several of which had topics directly or indirectly related to climate change.

One such project was KNOWBRIDGE (The Cross Border Knowledge Bridge in the Renewable Energy Sources Cluster in the Eastern Slovakia and North Hungary), which was implemented between 2009 and 2012 with the participation of Eastern Slovakia and Northern Hungary. The aim of the initiative was to create a cross-border innovation network in the field of renewable energy sources. The project implemented cluster development, prepared a joint strategic plan, and developed a mentoring and experience-sharing system to strengthen cooperation between regions. Its results contributed to expanding local research and development capacities and the utilization of renewable energies.

The other significant project was E-SOTER, which aimed to create a unified European database based on the digital processing of soil and terrain data. The project used GIS and remote sensing technologies to accurately map soil conditions and topography. Researchers from the University of Miskolc actively participated in field data collection, modeling, and thematic mapping tasks, including using drone sensor technologies and modern analysis software. The data obtained in this way became important tools for environmental assessment and sustainable land use planning.

The FP7 programme laid the foundation for later larger-scale research initiatives, such as Horizon 2020, and played a key role in strengthening the European Science and Innovation Area.

### **3.2. Horizon 2020 projects**

It was the EU's largest R&D funding initiative, with a budget of nearly 80 billion euros between 2014-2020. Its aim was to promote scientific excellence, strengthen industrial leadership and address environmental and societal challenges. The Faculty of Earth and Environmental Engineering was the most successful applicant and project implementer in the field of earth sciences in Hungary with 7 winning applications (KINDRA, INTRAW, UNEXMIN, CHPM2030, GROW Observatory, ROBOMINERS, REFLECT). I would like to briefly describe the purpose and relevance of these projects below.

#### *UNEXUP – UNEXMIN Upscaling*

The project is a continuation of the UNEXMIN H2020 program implemented between 2016-2019, in which an autonomous robot was developed to map flooded mines. The new phase aims to build on previous achievements by creating advanced robots that can explore up to 1500 meters deep. These robots will collect geological and mineralogical data using 3D mapping to help make decisions about reopening abandoned European mines, thereby contributing to reducing our dependence on rare earth metals, critical raw materials (which are essential for e.g. electronic devices, batteries). No similar device currently exists, so the development is groundbreaking. UNEXMIN GeoRobotics Ltd. will operate as a spin-off company after the project is completed.<sup>123</sup>

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<sup>1</sup> <https://www.unexmin.eu/> (Accessed: 14 May 2025)

<sup>2</sup> Zajzon et al., 2023.

<sup>3</sup> Zajzon et al., 2017.

### *ROBOMINERS*

The project, implemented with the participation of 14 international partners, aims to create a new type of mining ecosystem that combines developments in robotics and other scientific fields. The project focuses on a small, amphibious – i.e., operating both on land and underwater – mining robot swarm, capable of extracting hard-to-reach or small-volume ore deposits. The robots are sent deep into the ground through medium-diameter boreholes, where their modules assemble independently. Their sensor systems enable them to recognize their environment, control and optimize extraction. During their work, they create mineral mud, which is transported to the surface for processing. The project aims to build a TRL 4–5 prototype and test it in the laboratory.<sup>456</sup>

### *REFLECT*

The REFLECT (Redefining geothermal fluid properties at extreme conditions to optimise future geothermal energy extraction) project was implemented under the European Union's Horizon 2020 programme between 2020 and 2023, with a grant of nearly €5 million. The project aimed to increase the efficiency of geothermal energy exploitation by preventing problems caused by chemical reactions in heat-carrying fluids, such as precipitation, corrosion and gas evolution.

Within the framework of REFLECT, researchers collected new, high-precision data on the physical, chemical and microbiological properties of geothermal fluids under extreme temperature and pressure conditions. These data contributed to the creation of a European geothermal atlas and the development of predictive models that help to optimally operate geothermal systems and prevent unwanted reactions.

The project collected more than 80 fluid samples from various European geothermal sites and conducted laboratory experiments to investigate the effects of precipitation, gas evolution and microbial activity. These results allowed for the optimization of the design and operation of geothermal power plants, reducing maintenance costs and increasing energy efficiency.

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<sup>4</sup> <https://robominers.eu/> (Accessed: 14 May 2025)

<sup>5</sup> <https://robominers.eu/publications/> (Accessed: 14 May 2025)

<sup>6</sup> Berner and Sifferlinger, 2024.

The REFLECT project was coordinated by the German GFZ Helmholtz Centre for Geosciences and the consortium included 14 partners, including the University of Miskolc.<sup>78</sup>

### *CHPM 2030*

The CHPM2030 (Combined Heat, Power and Metal extraction) project aimed to develop an innovative technology that enables simultaneous geothermal energy and metal extraction from ultra-deep ore bodies.

Its main objectives included the development of a technology that combines geothermal energy production and metal extraction, especially at depths where conventional mining is not economical, the conversion of ultra-deep ore bodies into artificial geothermal systems capable of producing heat and electricity while the heat transfer fluid transports dissolved metals to the surface, and last but not least the development of a technology for metal extraction from the returning fluid, including nanotechnology solutions such as targeted metal ion adsorption.

The results of the project could contribute to increasing Europe's raw material and energy independence and create new opportunities for sustainable resource utilization.<sup>910</sup>

### *GROW Observatory*

The project, which ran from 2016 to 2019, aimed to create a sustainable, community-based observation system for monitoring soil moisture and land use, supporting precision agriculture, sustainable irrigation and land use.

One of its main objectives was to implement “Citizen Science”, involving more than 20,000 European smallholder farmers and gardeners who collected data on their own land using low-cost soil moisture sensors. The data collected contributed to improving the accuracy of Sentinel-1 satellite soil moisture measurements and to developing sustainable land use practices. Based on the experience gained and accumulated during the project, online courses and local workshops were organized for participants

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<sup>7</sup> <https://www.reflect-h2020.eu/> (Accessed: 14 May 2025)

<sup>8</sup> <https://www.reflect-h2020.eu/scientific-publications/> (Accessed: 14 May 2025)

<sup>9</sup> <https://www.chpm2030.eu/> (Accessed: 14 May 2025)

<sup>10</sup> CHPM2030 Overview and project results [Online]. Available at: [https://eurogeologists.eu/wp-content/uploads/2019/06/CHPM\\_results-Delft\\_2019\\_05\\_22.pdf](https://eurogeologists.eu/wp-content/uploads/2019/06/CHPM_results-Delft_2019_05_22.pdf) (Accessed: 14 May 2025).

to learn about regenerative agriculture methods and soil monitoring techniques.

The project created a unique, high-resolution soil moisture database that serves as a valuable resource for researchers and policymakers. The GROW Observatory has shown how citizen science tools can be used to promote sustainable agriculture and environmental monitoring.<sup>11</sup>

### ***3.3. EIT Programmes***

The European Institute of Innovation and Technology (EIT) is a flagship initiative of the European Union, aiming to foster innovation by connecting education, research and entrepreneurship. The EIT RawMaterials partnership within the EIT focuses on increasing the security of raw materials supply and improving the sustainability of the raw materials value chain.

The EIT's main objectives in the field of raw materials and sustainability are to strengthen the raw materials industry in Europe, with a particular focus on critical raw materials (e.g. rare earths), to support the sustainable use of resources along the entire value chain from mining to recycling, to promote the circular economy by improving the efficiency of material use and to support the green transition by providing the raw materials needed to mitigate climate change (e.g. electric mobility, battery production, renewable energies).

In addition, education development and knowledge transfer are also a key goal of the EIT RM, to create innovative educational programs (e.g. international MSc programs – AMIR, TIMREX, summer universities) to train future raw materials specialists. Below I would like to mention a few EIT programs implemented with the participation of the University of Miskolc.

#### ***AMIR-RIS***

AMIR-RIS is a two-year master's degree program that focuses on different stages of the raw materials life cycle, especially recycling. The goal is to train professionals who have in-depth knowledge in the field of materials technology and are open to innovation and entrepreneurial thinking.<sup>12</sup>

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<sup>11</sup> <https://growobservatory.org/> (Accessed: 14 May 2025)

<sup>12</sup> <https://www.amir-master.com/> (Accessed: 14 May 2025)

### *REEBAUX*

The REEBAUX project investigated how to extract rare earth metals from bauxite and bauxite processing waste (e.g. red mud) in the ESEE region. The project provided guidance for future research and technological developments in this area.<sup>13</sup>

### *ESEE Education*

ESEE Education aims to improve education on raw materials in the Eastern and South-Eastern European region. The programme includes training at different levels, from school lessons to university courses and professional development.

### *MineTALC*

The MineTALC project aimed to improve the efficiency of backfill mining of low and medium-strength ore bodies. To this end, new technical solutions and mining methods were developed, considering environmental aspects.

### *RM@Schools*

RM@Schools is an educational initiative that brings raw materials science closer to students. The programme presents the role of raw materials and the importance of their responsible and sustainable use through interactive activities and experiments.<sup>14</sup>

## **3.4. LIFE projects**

The LIFE programme is one of the oldest and most important funding instruments of the European Union for the environment and climate action. It has been in operation since 1992 and has supported more than 5,500 projects across Europe.

The main aims and objectives of LIFE projects are to protect nature and biodiversity, with particular regard to Natura 2000 sites, to address environmental challenges such as reducing air, water and soil pollution, improving waste management, mitigating and adapting to climate change, supporting sustainable energy use and energy efficiency, and to help implement policy and legal instruments to achieve EU environmental and climate policy objectives.

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<sup>13</sup> <http://reebaux.gfz.hr/> (Accessed: 14 May 2025)

<sup>14</sup> <https://rmschools.isof.cnr.it/> (Accessed: 14 May 2025)

In the LIFE 2021-2027 cycle, projects can be implemented in the following areas:

1. Nature and biodiversity
2. Circular economy and quality of life
3. Climate change mitigation and adaptation
4. Clean energy transition

The following activities must be implemented within the framework of the projects:

- LIFE projects offer practical, on-site solutions to environmental and climate challenges.
- Support the testing and demonstration of innovative technologies.
- Promote the dissemination and adoption of good practices.
- Pay special attention to systemic impacts and the preparation of policy measures.

The LIFE programme does not require co-financing from participating countries, making it a particularly useful tool for municipalities, research institutions, civil society organisations and businesses to achieve their environmental and climate goals.

In recent period, the technical faculties of the University of Miskolc have directly participated in 2 LIFE programs: LIFE IP HungAIRy and LIFE CLIM-COOP.

#### *LIFE IP HungAIRy*

This project aims to improve the air quality of Hungary in the long term. The program is implemented in ten Hungarian cities, including Miskolc, and focuses mainly on reducing air pollution from residential heating, transport and industrial activities. The project involves the preparation of new air quality plans, modern data collection and public awareness-raising. The aim is to reduce the concentration of particulate matter and other harmful substances in urban air through the cooperation of decision-makers and the public.<sup>15</sup>

#### *LIFE CLIMCOOP*

This project promotes adaptation to the effects of climate change, in a unique way through joint action between the municipality and industry. The

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<sup>15</sup> <http://hungairy.hu/> (Accessed: 14 May 2025)

pilot site is Kazincbarcika, where the city and the BorsodChem company are working together to develop a climate adaptation strategy. Practical steps include expanding green areas, introducing rainwater management solutions and mitigating the effects of heat waves and flash floods. The project aims to create a model of cooperation that other cities can follow.<sup>16</sup>

#### **4. National projects**

Last but not least, I would like to provide a brief overview of the currently larger domestic project aimed at climate protection and mitigation of the effects of climate change. The National Laboratories program is one of Hungary's priority research and development initiatives, launched within the framework of the Recovery and Resilience Plan (RRF). The program aims to strengthen the domestic research and innovation ecosystem, especially in areas that provide answers to the challenges of the future economy and society.

National laboratories are research centers where universities, research institutes and industrial partners work together on long-term, strategically important scientific and technological goals. The focus is on digital transition, artificial intelligence, green technologies, climate change and the transformation of energy systems. The technical faculties are actively involved in 3 such National Laboratory projects: Multidisciplinary National Laboratory for Climate Change (ÉMNL), National Laboratory for Water Science and Water Security (VVNL), National Laboratory for Renewable Energies.

##### *Multidisciplinary National Laboratory for Climate Change (ÉMNL)*

This laboratory investigates the complex issues of climate change, with particular attention to its environmental, economic and social impacts. The research aims to understand the factors that trigger climate change and their impacts on nature and human societies. In addition, the laboratory also deals with the development of technological, economic and social adaptation strategies to help communities prepare for changing environmental conditions. Within the framework of subprojects 7A and 7B, the University of Miskolc is working on the development of raw material production processes and methodologies for CO<sub>2</sub>-intensive industries, and on the development of low-cost sensor networks for recording environmental data

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<sup>16</sup> <https://life-climcoop.hu/> (Accessed: 14 May 2025)

in agricultural and settlement environments, and on the development of geoinformatics methodologies to support decision-making.<sup>17</sup>

*National Laboratory for Renewable Energy*

This laboratory conducts research in the field of renewable energy sources, especially hydrogen technologies and carbon capture and storage (CCU). Its goal is to develop and test technologies that enable the production and storage of clean energy and the environmentally friendly utilization of carbon dioxide. The laboratory also performs economic and legal analyses to facilitate the integration of these technologies into the industrial and energy sectors.<sup>18</sup>

*National Laboratory for Water Science and Water Security*

This laboratory focuses on issues of water management and water security. Its research includes the assessment of the status of surface and groundwater bodies, monitoring water quality, and the study of aquatic ecosystems. The laboratory aims to contribute to the development of sustainable water management practices and to increase water security, especially in the face of challenges caused by climate change and human activities.<sup>19</sup>

*FLUMEN project – Hydrogen blending in the natural gas network*

The FLUMEN project is a joint research and development initiative launched by the University of Miskolc and FGSZ Földgázszállító Zrt. The aim of the project is to map the transport options for a mixture of hydrogen (10%) and natural gas in the domestic natural gas system, thereby contributing to Hungary's climate neutrality efforts. The project will build and test a pilot system that will enable the safe transport of hydrogen-enriched natural gas, and will develop measurement, monitoring and accounting methods for the mixture of hydrogen and natural gas.

The technical implementation will be carried out in two phases. In the first phase, the system components required for the transport of hydrogen-

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<sup>17</sup> <https://www.uni-miskolc.hu/palyazati-tevekenysege/elnyert-hazai-es-nemzetkozi-palyazatok/rrf-2-3-1-21-2022-00014/> (Accessed: 14 May 2025)

<sup>18</sup> <https://www.uni-miskolc.hu/palyazati-tevekenysege/elnyert-hazai-es-nemzetkozi-palyazatok/rrf-2-3-1-21-2022-00009/> (Accessed: 14 May 2025)

<sup>19</sup> <https://palyazatok.uni-miskolc.hu/RRF-2-3-1-21-2022-00008-viztudomanyi-es-vizbiztonsagi-nemzeti-laboratorium> (Accessed: 14 May 2025)

enriched natural gas will be designed and tested. In the second phase, the operation of the entire system will be evaluated and optimized.

In addition to all these domestic and international projects, numerous industry-induced and financed R&D projects (Market R&D+I) have been and are being implemented to this day, which may have domestic and international patents, contributing with their results to increasing sustainability, combating climate change, and reducing the effects of climate change (utilization of lignite for agricultural purposes, testing of rare earth metal content; testing and extracting lithium content of subsurface fluids, precision agriculture – smart irrigation technologies, development of irrigation decision support systems).<sup>20</sup>

## **5. Conclusion**

In the study, I tried to summarize and demonstrate through good practices that the 3 faculties of the University of Miskolc operating in the technical training areas are active players and sometimes shapers of the fight against climate change and the increase of economic sustainability from an environmental perspective. Thanks to continuous monitoring and reviews, both undergraduate and postgraduate trainings are characterized by renewal, updated knowledge transfer and practice orientation, and the issues of the challenges of our time are integrated into the model curricula, as well as the answers to questions and challenges, for which the results of successful domestic and international R&D projects provide a good basis. The network of contacts between the lecturers and researchers of the technical faculties (higher education and industry), as well as the modern infrastructural features of the faculties, provide an excellent basis for the University of Miskolc to continue to be one of the leading knowledge centers of Hungary and Central and Eastern Europe in the 21st century, even in the fields of green transition, sustainability and the fight against climate change.

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<sup>20</sup> <https://www.uni-miskolc.hu/palyazati-tevekenyseg/elnyert-hazai-es-nemzetkozi-palyazatok/flumen-projekt-2-fazis/> (Accessed: 14 May 2025)

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